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COSHOCTON-TYPE
RUNOFF SAMPLERS

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COSHOCTON-TYPE RUNOFF SAMPLERS

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Supplementary Laboratory Investigations at the Stillwater, Okla., Outdoor Hydraulic Laboratory

by
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Soil and Water Conservation Research Branch

Following completion of the work on the Coshocton sampler at the St. Anthony Falls Hydraulic Laboratory of the University of Minnesota, a number of the 1-ft samplers of a type described in SCS - TP - 124 were installed at experiment stations [1/] for observation. They were generally placed in series with Geib [2/] multislot devisors or other similar installations to provide a check on the soil loss and runoff measurements. The results of these field trials during 1952 and 1953 were unexplainably erratic. Also, great difficulty was experienced in the Southeast with deposition of sand in the approach trough and H-flume upstream from the sampler.

These experiences prompted a cooperative effort by the Watershed Hydrology Section and the Eastern Soil and Water Management Section of the Soil and Water Conservation Research Branch to determine and correct, if possible, the causes for the relatively poor showing of the devices in the field. This work was done at the Stillwater, Okla., Outdoor Hydraulic Laboratory [3/], during the period April 22 to June 4, 1954.

1/ The following men participated in the trials:

George N. Sparrow, Tifton, Georgia
A. P. Barnett, Watkinsville, Georgia
John R. Carreker, Watkinsville, Ga.
Orville E. Hays, LaCrosse, Wisconsin
L. A. Forrest, Raleigh, N. C.
F. W. Schaller, Ames, Iowa.
H. E. Middleton, Beltsville, Md.
T. W. Edminster, Beltsville, Md.

2/ Mention of manufacturers does not constitute endorsement of their products by the U. S. Department of Agriculture.

3/ W. O. Ree and his entire staff at the laboratory were most helpful. Their consistent and skillful aid materially expedited the work.

The tests were limited to the 1-ft diameter sampler. The sampler used was constructed in the Plant Industry Station shop at Beltsville, Maryland. The essential measurements of the experimental device are shown in Figure 1 and a photograph in Figure 2.

One of the five 20-inch syphons at the Laboratory was tapped with a 6-inch line that extended into a field shelter. The water flow was controlled with a 6-inch gate valve and measured by point gage and 1-ft H-flume. The flow from the H-flume was spread across the upper end of a sloping surface that was 6 feet wide and 6 feet long. The surface was galvanized sheet steel, firmly supported by wooden flooring and timbers. Its purpose was to simulate an experimental erosion plot. A collecting trough at the foot of the sloping surface concentrated the water (runoff) at the plot centerline in a manner similar to the usual method in making soil loss and water runoff measurements.

Sand was used for the erodible material since the field trials showed that the greatest difficulties were found with installations on sandy soils. The sand was spread manually across the upper portion of the sloping surface during a test. The water then transported the material to the collecting trough. The size distribution of the sand is shown in Table 1.

TABLE 1 - The Size Distribution of the Sand

Size	Percent
Gravel	3
Coarse Sand	6
Medium Sand	44
Fine Sand	40
Very fine sand	4
Silt and clay	3

BEARING FRICTION STUDIES

A measure of bearing friction in the experimental sampler was sought. Also desired was a method of measurement for ready field determination of friction. The bearing friction data that were obtained are given in Figure 3. The total time lapses for several numbers of revolutions of the decelerating wheel, following an initial impulse, were recorded.

The fact that straight lines may be drawn to closely represent the data when plotted as in Figure 3, implies that the friction or resistance to turning is not affected by the rate of turning. The nature of the resistance is therefore like that of dry friction between two moving solids. However, experience [4] has shown that the resistance of lubricated bearings at low speeds does not conform with the functional relationship between friction and relative velocity of the moving parts that holds for the higher speeds.

The slopes of the lines, designated S in Figure 3, are a measure of the friction torque or moment of force causing deceleration of the rotating wheel with time. Except for test No. 1 there was a progressive decrease in torque with successive trials that happened to coincide with a progressive increase in air temperatures. This suggests the possibility that bearing oil viscosity progressively decreased with temperature and affected friction torque. This might well be given more study.

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[4] "The Mechanical Properties of Fluids", Blakie & Son,Ltd., Glasgow, page - 139 (1925)

The average value of S is .0022 and the mean kinetic friction torque is:

$$\text{F.T.} = 4\pi I \bar{S}$$

$$= 4\pi\,(0.027)\,(.0022) = .00075 \text{ ft.-lbs.,}$$

where I is the moment of inertia of the wheel about its center.[5]

The starting torque of the wheel that was used appeared to be a little too great. Whereas two 1/2 inch inside diameter radial bearings were used, a trial with bearings of about 0.3 inch should be made in an effort to reduce the torque.

SAND DEPOSITION STUDIES

The experimental work was necessarily exploratory at the beginning. After it was learned that the major difficulty was deposition in the approach to the sampler, cut and try methods were used in an endeavor to find approach trough designs that would reduce the difficulty. Many things were tried and discarded after unrecorded observations. Rather complete measurements were made only when it seemed that an acceptable design was being approached.

[5] The moment of inertia of the wheel was determined by using it as a part of a torsion pendulum. It was rigidly connected at its center to the lower end of a long, small-diameter metal rod that was fastened securely to a support at the upper end. The moment of inertia is proportional to the square of the vibration period. The pendulum was calibrated by replacing the wheel with metal disks, for which the moments of inertia were easily calculated.

TABLE 2

TEST DATA - STILLWATER, OKLAHOMA TESTS OF COSHOCTON-TYPE RUNOFF SAMPLER, N-1

TEST NO.	DATE (1954)	APPROACH DESIGNATION	FLOW,Q	SAND TO PLOT	SAND CONCENTRATION OF PLOT RUNOFF	SAND IN APPROACH CHANNEL	SAND PASSING SAMPLER H-FLUME,S	WATER SAMPLE	TEST TIME	SAMPLER FLOW,q	WATER RATIO R is q/Q	SAND(1) SAMPLE,s	SAND RATIO (1) Rs is s/S	WHEEL SPEED	APPROACH VELOCITY
			cfs.	lbs.	pct. by wt.	lbs.	lbs.	lbs.	sec.	cfs.		lbs.		rpm.	ft/sec
1	5-11	A-1	0.201	59.7	1.0	45.9	13.8	64.57	472.8	.00219	.01092	0.146	.0105		
2	5-13	A-1	0.201	99.0	1.9	58.5	40.5	54.11	420.2	.002067	.01028	0.328	.0081		
3	5-14	A-1	0.201	32.7	0.6	23.5	9.2	56.95	437.6	.00209	.01030	0.084	.0091		
4	5-14	A-1	0.1026	33.6	1.1	29.6	4.0	30.61	475.4	.001024	.00998	0.035	.0088		
5	5-14	A-1	0.1018	65.2	2.4	53.9	11.3	32.40	479.6	.001085	.01065	0.100	.0088		
6	5/15	A-1	0.300	64.3	1.4	39.7	24.6	47.10	252.2	.003000	.01000	0.231	.0094		
7	5-16	A-2	0.205	64.3	1.2	12.0	52.3	54.36	411.6	.002120	.01035	0.480	.0092		
8	5-17	A-2	0.0986	67.4	2.3	21.8	45.6	28.32	---	---	---	0.457	.0100		
9	5-17	A-2	0.300	99.4	2.0	25.6	73.8	46.65	261.2	.00287	.00957	0.685	.0093		
10	5-18	A-3	0.198	69.9	1.2	9.5	60.4	59.80	472.2	.002032	.01027	0.599	.0099		
11	5-18	A-3	0.299	108.2	2.3	17.2	91.0	46.07	253.6	.002918	.00976	0.760	.0084		
12	5-20	B-1	0.200	67.9	1.1	1.1	66.8	60.54	486.4	.001997	.00999	0.665	.0100		
13	5-21	B-1	0.300	100.5	3.0	3.1	97.4	31.20	181.2	.002766	.00922	0.995	.0102		
14	5-21	B-1	0.0994	35.8	---	4.1	31.7	13.57	---	---	---	0.270	.0085		
15	5-26	B-2	0.1002	---	---	1.6	---	28.08	490.2	.000920	.00917	0.549	---		
16	5-31	C-1	0.194	37.0	2.2	5.3	31.7	18.13	141.6	.002055	.01059	0.315	.00995	47	4.8
17	5-31	C-1	0.201	33.0	1.7	0.9	32.1	19.07	153.6	.001992	.00991	0.318	.00990	48	6.5
18	5-31	C-1	0.0506	32.9	2.1	2.2	30.7	15.70	489.6	.000515	.01018	0.305	.00995	27	3.9
19	6-1	C-1	0.0501	34.8	2.2	0.1	34.7	16.13	503.5	.000514	.01027	0.360	.01038	33.5	4.9
20	6-1	C-1	0.0253	17.9	2.3	2.2	15.7	8.07	500 ±	.000259	.01024	0.141	.00896	36	3.6
21	6-1	C-1	0.0257	17.9	2.2	0.4	17.5	7.69	506.5	.000244	.00949	0.161	.00917	33.5	5.0
22	6-4	B-3	0.197	70.9	2.4	1.3	69.6	28.90	245.6	.001890	.00960	0.647	.00929		
23	6-4	B-3	0.0979	68.0	2.3	1.2	66.8	28.02	474.8	.000948	.00969	0.629	.00941		
24	6-4	B-3	0.0516	32.8	2.1	2.9	29.9	15.38	476.0	.000519	.01006	0.305	.01021		
25	6-4	B-3	0.0250	18.5	2.3	2.5	16.0	8.07	511.2	.000254	.01014	0.162	.01014		

TABLE 3 - Mean Values from Sampler Tests

Approach Channel Designation	No. of Tests	Sand Deposition Upstream from Sampler lbs.	Proportion of Total Runoff Retained by Sampler	
			Water	Sand*
B-3**	4	2.0	.0099	.0101
C-1	6	1.9	.0101	.0100

* Proportion of sand delivered to sampler that was retained.

** Tested with near-equal flows from each end of the collecting trough. Greater deviations in sampler catch should be expected for extreme asymmetry of flow in the collecting trough.

(7) A small amount of sand deposited on the wheel plate near the end of runoff appeared to produce no serious effects on sampler operations.

(8) Tests were made to determine the horizontal clearance required for hoods that may be used to protect the sampler wheel from wind, small boys, etc. A minimum clearance of 2-inches for the 1-foot diameter wheel is necessary. A greater distance would be preferable, especially if possible trash difficulties are considered.

(9) Although care was used in handling the sampler during the tests, it is still significant that no difficulty was experienced with either sand or water in the bearing.

(10) The slope of the wheel plate in the sampler that was used for the tests was 0.186 (1 on 5.3) instead of 0.10 specified on the plans. This increases the required headroom for operation by one inch. The beneficial effect of the increase in slope, is an increase in the turning moment of force for trickle flows.

The use of a bearing assembly with greater friction than in the original design for the purpose of reducing the wobble of the wheel makes an increase in tilt of the wheel desirable in a future design.

(11) A small amount of sand was caught in the pan in each test. The pan outlet was a street elbow attached to the bottom of the pan, that requires 2 inches headroom more than the current plans indicate. This street elbow outlet is probably much better than the one shown on the plans from the standpoint of catching sand, but neither of them is good. A new design should be developed that will pass sand better without an increase in headroom requirement. (Two inches extra headroom, for example, requires 5 feet of extra digging at the deep end of the trench for a plot on a 3% slope).

(12) Experience with heavy sand loads in the runoff suggests that adequate slope of the conduit between the sampler and the sample tank must be provided. Minimum slope requirement was not determined. For this condition a minimum slope of five percent is suggested on a trial basis.

(13) A few tests with trash, (bermuda grass, both dead and green) demonstrated that the wheel could be stopped by the trash wedging between the wheel and the downstream portion of the H-flume support. This support should be redesigned to provide greater clearance for the wheel.

(14) The H-flume approach to the sampler should not be depended upon as a flow measuring device when preceded by approach B-3 or C-1.

The several sand moisture determinations that were required in each test to put the erodible material on a dry weight basis made the test procedure quite cumbersome. Test data are summarized in Table 2. Plans for the two approach designs, designated B-3 and C-1 and judged to be most suitable, are shown in Figures 4a, 4b and 5.

A summarization of the results of the work includes the following:

(1) A large amount of deposition occurred within the H-flume and the approach channel when a 2 foot long, level channel with width equal to the upstream end of the H-flume was used. For example, in Test No. 1, there was about 45 lbs. of sand deposited above the sampler, which would be equivalent to more than one ton per acre for a .02-acre plot.

(2) The amount of deposition generally increased with the rate of sand feed or sand concentration of the runoff.

(3) The sampler behaved in general as expected from the Minnesota tests; i.e., both the sand and water fractions retained by the sampler were reasonably correct as long as the wheel speeds were at or near those obtained in the original calibration tests.

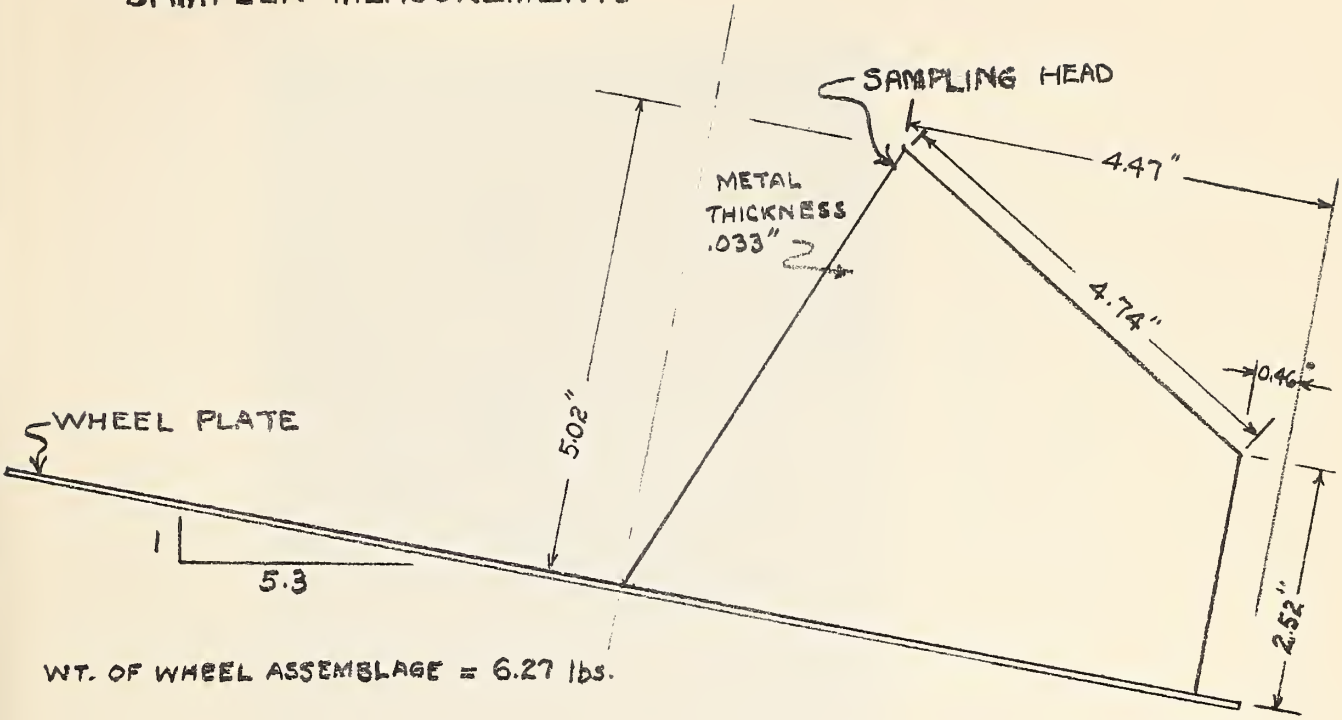
(4) The rate of turning of the wheel was sensitive to differerences in approach conditions. This was the basic reason for originally adopting the H-flume approach as an integral part of the sampler. The Oklahoma tests showed, however, that approach conditions to the H-flume that caused seemingly minor changes in the H-flume jet changed the wheel

speeds materially. Deposition in the approach channel could therefore affect wheel speeds and the catch of the sampler by alteration of the H-flume jet. As an illustration of the effect of wheel speed on the sampler catch, an unrecorded measurement of the water sample, obtained at a wheel speed double the normal rate of turning, showed the sample to be 18% low.

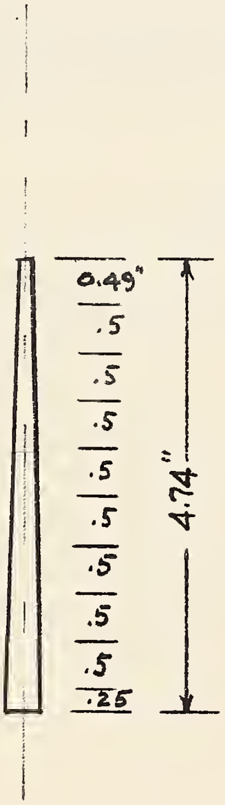
(5) Whereas the Minnesota tests showed that the proportion of coarse sand retained by the sampler increased materially with flow rate, the medium to very fine sand used in the Oklahoma tests was retained by the sampler more nearly as the water was retained.

(6) Since the preliminary exploratory tests demonstrated that the major difficulty in the use of the equipment was upstream sedimentation, the later work was concentrated upon development of approach channel designs that would reduce this difficulty. Although a large number of new designs were tried, only four of them were seriously considered as being adequate, and only two of these were accepted as the end products. One design, approach C-1, is for use when the runoff comes to the sampler at high velocity (5 to 9 ft./sec.) through a pipe or narrow channel, and the other, approach B-3, is for direct connection to the collecting trough at the foot of the experimental plot area. Mean values of the test results obtained at flows ranging between .025 and 0.20 cfs. are given in Table 3 for these designs.

Figure 1.-
SAMPLER MEASUREMENTS

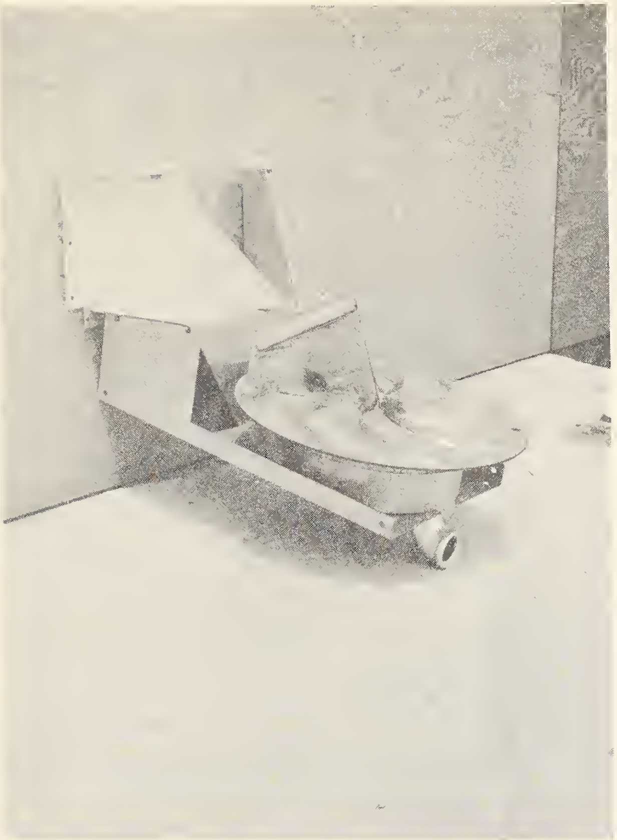


WT. OF WHEEL ASSEMBLAGE = 6.27 lbs.



POSITION	SLOT WIDTH, INS TRIAL NO. 1	2	MEAN	SPEC.	DIFF.
1	.150	.150	.150	.142	.008
2	.172	.172	.172	.164	.008
3	.193	.192	.193	.187	.007
4	.216	.214	.215	.210	.005
5	.232	.232	.232	.232	.000
6	.250	.250	.250	.255	-.005
7	.275	.274	.274	.277	-.003
8	.297	.297	.297	.300	-.003
9	.320	.320	.320	.323	-.003

FIGURE 2



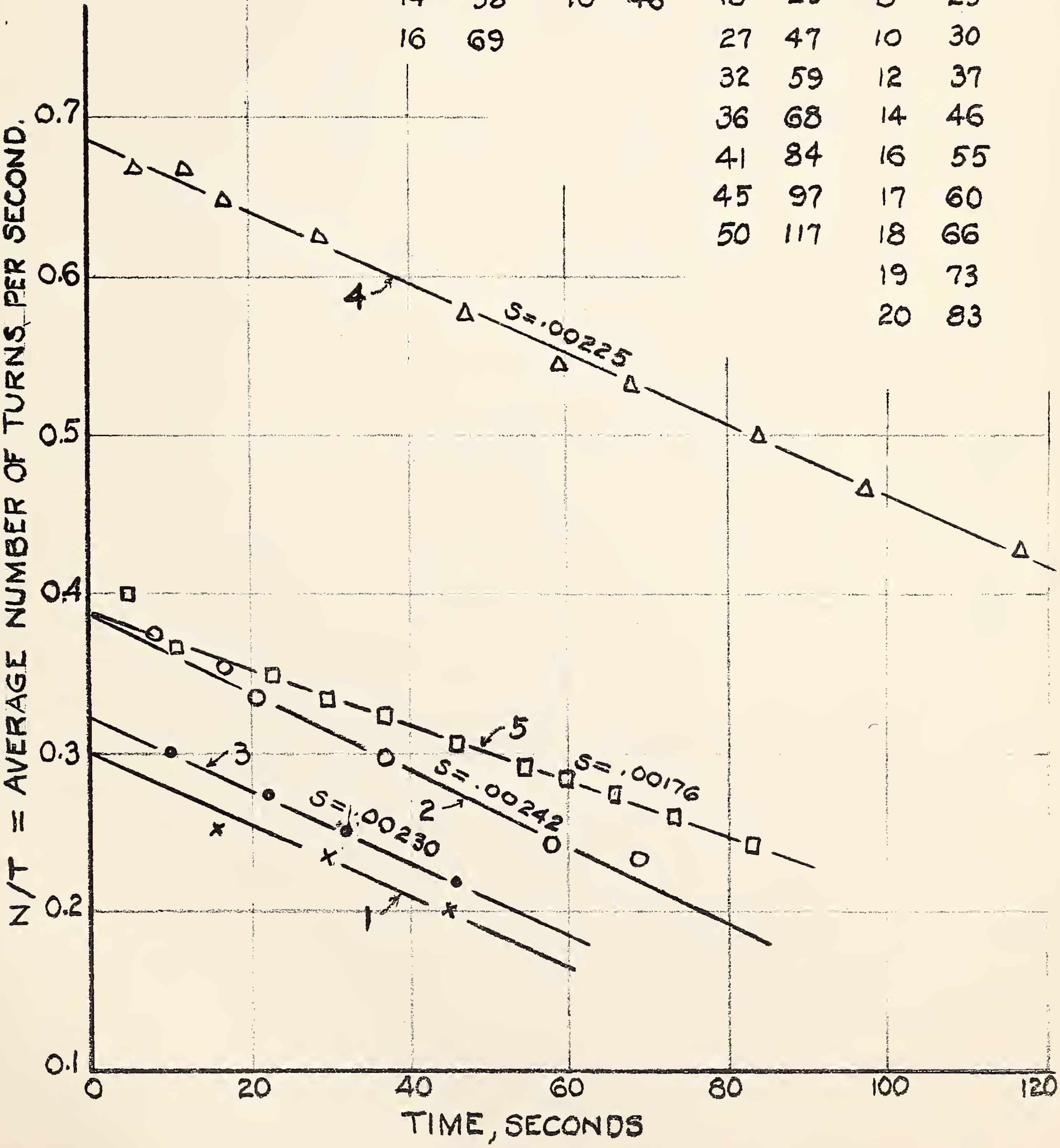
1 - ft. COSHOCTON TYPE
RUNOFF SAMPLER

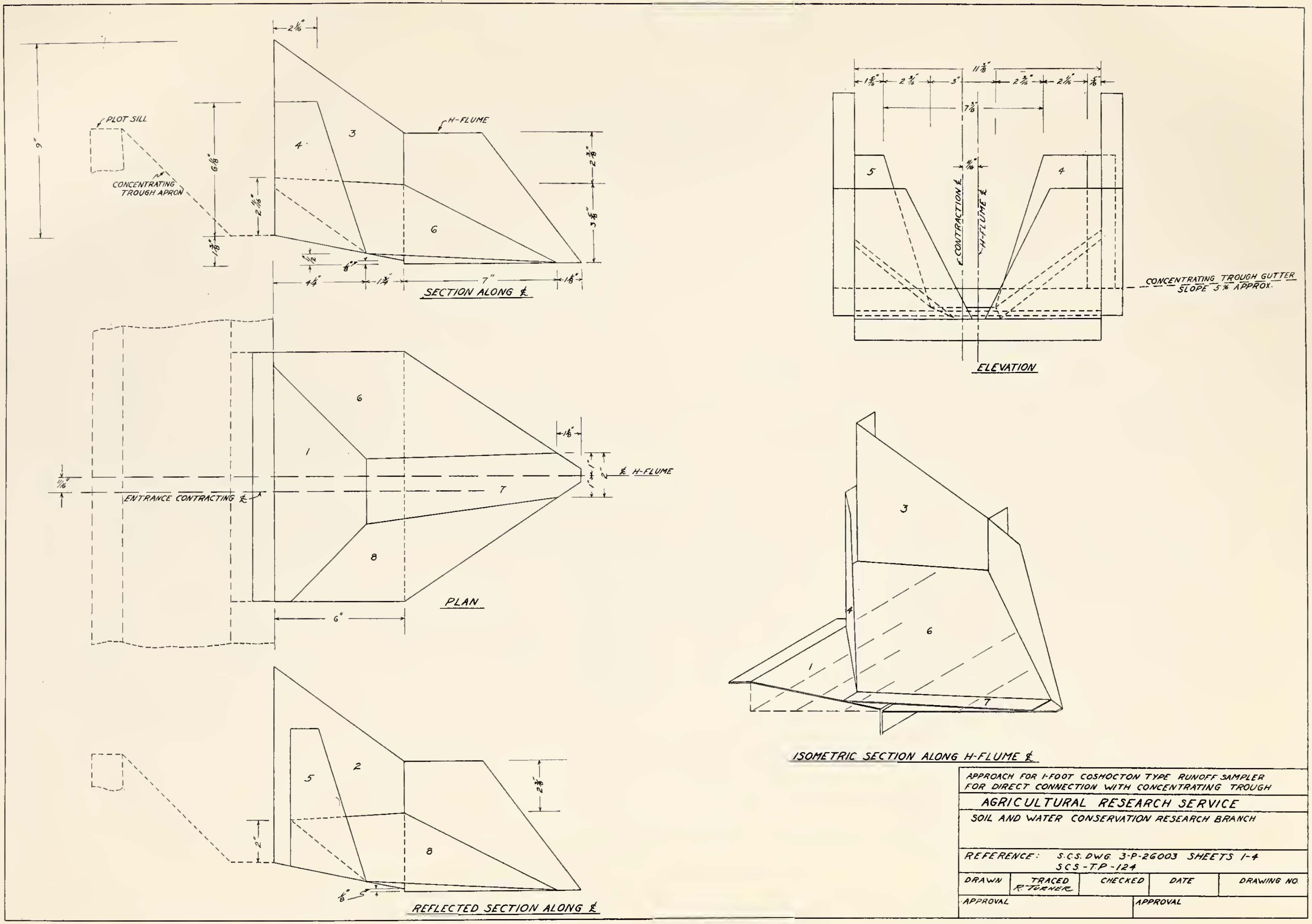
Constructed in Plant Industry Station
Shop, Beltsville, Maryland

FIGURE 3

FRICTION TORQUE DATA

TEST NO. 1		2		3		4		5	
N	T	N	T	N	T	N	T	N	T
0	0								
4	16	3	8	3	10	4	6	2	5
7	30	7	21	6	22	8	12	4	11
9	45	11	37	8	32	11	17	6	17
		14	58	10	46	18	29	8	23
		16	69			27	47	10	30
						32	59	12	37
						36	68	14	46
						41	84	16	55
						45	97	17	60
						50	117	18	66
								19	73
								20	83





SECTION ALONG ℄
PLOT SILL
CONCENTRATING TROUGH APRON
H-FLUME
9"
6⅛"
7"
PLAN
ENTRANCE CONTRACTING ℄
℄ H-FLUME
6"
1"
2"
REFLECTED SECTION ALONG ℄
2"
ELEVATION
CONTRACTION ℄
H-FLUME ℄
CONCENTRATING TROUGH GUTTER SLOPE 5% APPROX.
3"
ISOMETRIC SECTION ALONG H-FLUME ℄
1
2
3
4
5
6
7
8
APPROACH FOR 1-FOOT COSHOCTON TYPE RUNOFF SAMPLER FOR DIRECT CONNECTION WITH CONCENTRATING TROUGH
AGRICULTURAL RESEARCH SERVICE
SOIL AND WATER CONSERVATION RESEARCH BRANCH
REFERENCE: S.C.S. DWG. 3-P-26003 SHEETS 1-4
SCS-TP-124
DRAWN
TRACED R. TURNER
CHECKED
DATE
DRAWING NO.
APPROVAL
APPROVAL

Figure 4 a - Approach B-3 (sheet 1 of 2)

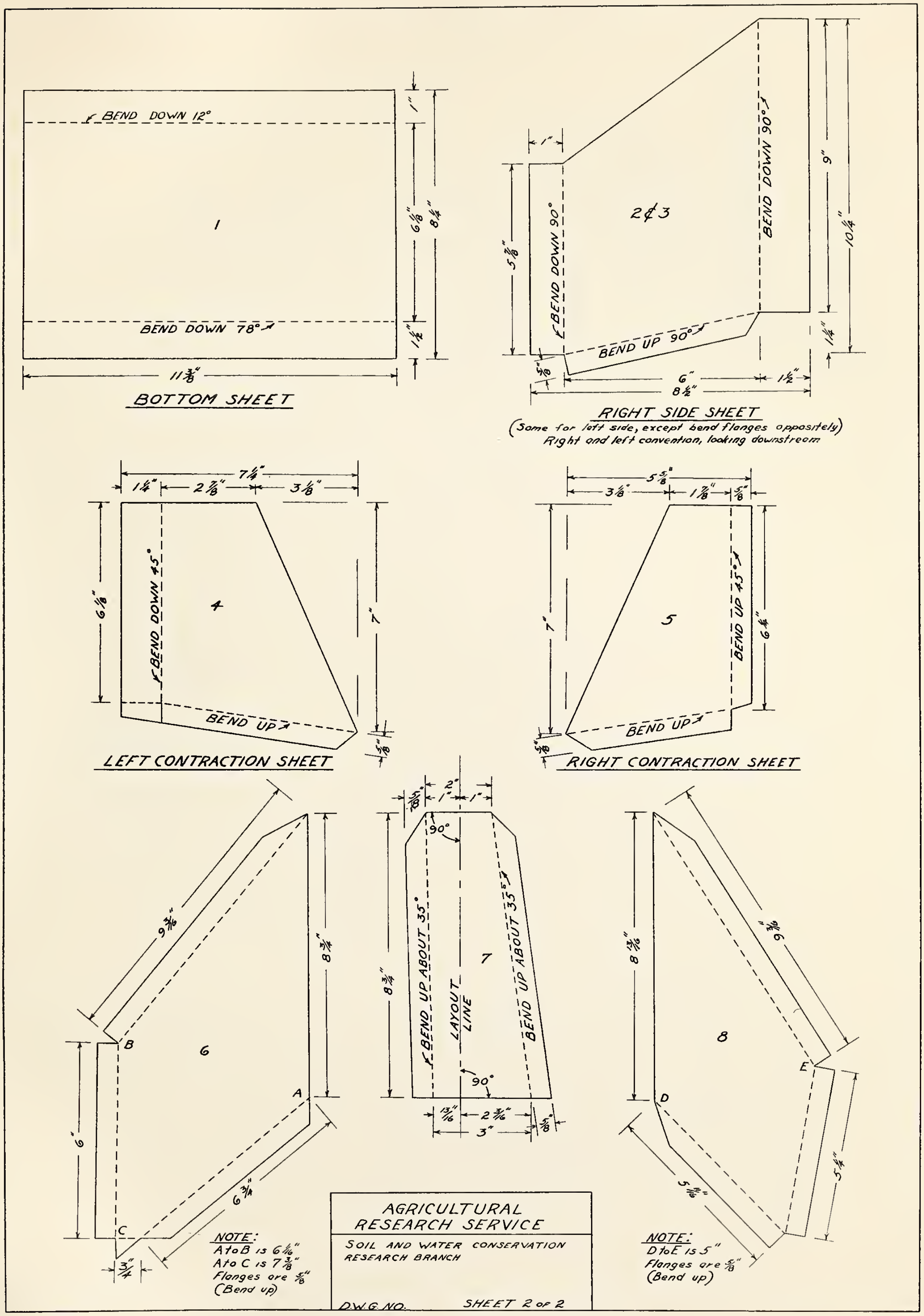


Figure 4 b - Approach B-3 (sheet 2 of 2)